

**IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
AUSTIN DIVISION**

RETHINK35, et al.,

Plaintiffs,

v.

TEXAS DEPARTMENT OF
TRANSPORTATION (TxDOT), et al.

Defendant.

§
§
§
§
§
§
§
§
§

CIVIL ACTION NO. 1:24-CV-00092

**DECLARATION OF KRISH VIJAYARAGHAVAN
IN SUPPORT OF PLAINTIFFS' MOTION FOR SUMMARY JUDGMENT**

I, KRISH VIJAYARAGHAVAN, do declare and state:

1. Attached hereto as Exhibit A is a true and correct copy of my March 29, 2025, report, which I wrote for this case.

2. If sworn as a witness, I could and would testify to my personal knowledge of the facts set forth in this declaration and to the facts and opinions set forth in Exhibit A.

I make this declaration under penalty of perjury under the laws of the United States of America, executed this 29th day of March, 2025, in Novato, California.

Respectfully submitted,



KRISH VIJAYARAGHAVAN

EXHIBIT A

Prepared for:

Greenfire Law, PC
Berkeley, CA 94703

Prepared by:

Krish Vijayaraghavan
Ramboll
7250 Redwood Blvd., Suite 105
Novato, California 94945

March 29, 2025

Expert Report in the Matter of RETHINK 35, et al. v. Texas Department of Transportation

Contents

1.0 Introduction	1
2.0 Overview	4
2.1 Determination of the Appropriate Level of NEPA Air Quality Analysis	4
2.2 Type of Project and Air Pollutants	4
2.3 Current Scientific Information	9
2.4 Failure to Establish Current Conditions in the Affected Environment.....	11
2.5 Methods used Conventionally for PM _{2.5} Analysis in an EIS.....	11
3.0 NEPA Analysis and Comments for the I-35 Project	14
3.1 Air Quality Analysis by TxDOT	14
3.2 Comments by Public and Participating Agencies	15
3.3 The Clean Air Act and NEPA	18
4.0 Supplemental EIS	20
5.0 Summary of Opinion	28

FIGURES

Figure 1. Particulate matter overview.	5
Figure 2. Locations of EPA Air Quality System monitoring stations near the project.	26

TABLES

Table 1. Measured air concentrations (design values) of PM _{2.5} near the project.....	26
---	----

APPENDIX

Appendix A. CV of Krish Vijayaraghavan

1.0 Introduction

My name is Krish Vijayaraghavan. I am a Principal at Ramboll Americas Engineering Solutions, Inc. (Ramboll) in the U.S. Environment and Health division.

I have 25 years' experience in environmental practice and specialize in National Environmental Policy Act (NEPA) environmental reviews and air quality modeling and analysis.

In my current employment, I train and manage air quality staff to support Environmental Impact Statements (EIS) & Environmental Assessments (EA) for surface transportation, aviation, mining, oil and gas, and other energy projects.

My technical expertise is in air pollution and greenhouse gas/climate analysis. I have conducted computer modeling studies and data analysis of photochemical air pollution (ozone, secondary $PM_{2.5}$ ¹), sulfur and nitrogen oxides, primary PM_{10} ¹ and $PM_{2.5}$, volatile organic compounds, ammonia, air toxics, and atmospheric deposition.

As a member of the National Association of Environmental Professionals (NAEP), I have conducted NEPA professional training workshops in the U.S. along with other colleagues from the NAEP. During these workshops, we explain the fundamentals of NEPA including the preparation of EIS and EA. The attendees include participants from regulatory agencies, consultancies, and industry.

I have published over forty peer-reviewed research papers, focused on air quality and related topics, and co-authored two technical book chapters.

I have performed the NEPA air quality analysis for over 20 EIS and EA for projects across the country, including in Texas. I led the air quality analysis for three

¹ $PM_{2.5}$ is fine inhalable particulate matter (PM) that is roughly less than 2.5 micrometers in diameter. PM_{10} is PM that is roughly less than 10 micrometers in diameter. PM_{10} is the sum of $PM_{2.5}$ and PM that is between 2.5 and 10 micrometers in size. Primary PM is released directly as particulates from sources while secondary PM is formed in the atmosphere from gases released from sources.

Supplemental Environmental Impact Statements (SEIS) under NEPA: (i) the 2024 U.S. Bureau of Land Management (BLM) SEIS for the Buffalo Wyoming Field Office Resource Management Plan (RMP) amendment², (ii) the 2024 BLM SEIS for the Miles City Montana Field Office RMP amendment³, and (iii) the 2024 BLM SEIS for the Coastal Plain Oil and Gas Leasing Program⁴. Almost all of the NEPA environmental reviews for EIS and EA that I worked on included emission sources which involved an analysis of PM_{2.5} from vehicles.

In 2024, I was retained by Plaintiffs in the Matter of *RETHINK 35, et al. v. Texas Department of Transportation* (TxDOT) to look at the TxDOT NEPA analysis of air quality that was conducted for the I-35 Capital Express Central Project from US 290 East to US 290 West/SH71 ("I-35 Project" or "Project"). In this capacity, I have been asked to form opinions regarding whether supplemental analysis under NEPA is required considering the U.S. Environmental Protection Agency's (EPA) new National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) smaller than 2.5 micrometers (PM_{2.5}). I have also been asked to explain technical terms or complex evidence associated with adoption of the I-35 Project.

My hourly compensation rate for this engagement is \$310/hour. The total compensation for our team is anticipated to be approximately \$40,000.

For this case, I reviewed relevant sections of the following documents:

- Plaintiffs' first amended complaint for declaratory and injunctive relief
- Defendant's first amended answer
- C-AR202 (Project Final EIS)
- C-AR211 (Appendix G: Comment/Response Matrix)
- C-AR220 (Appendix P on Air Quality)
- C-AR217 (section with City of Austin comments)
- C-AR077 (TxDOT environmental handbook)
- C-AR155 (TxDOT guidance on air quality statements)

² https://eplanning.blm.gov/public_projects/2021239/200533937/20110491/251010482/BFO_FSEIS_508.pdf

³ https://eplanning.blm.gov/public_projects/2021155/200534253/20110900/251010891/MCFO_Final%20SEIS_Proposed%20RMPA_508.pdf

⁴ eplanning.blm.gov/public_projects/2015144/200492847/20122648/251022628/Coastal%20Final%20SEIS_CR_Vol1_20241101_508_updated.pdf

- C-AR032 (Near-Road Particulate Pollution: PM_{2.5}, Black Carbon, and Ultrafine Particles at U.S. Near-Road Monitoring Sites)
- C-AR283 (89 FR 16202 - Reconsideration of the National Ambient Air Quality Standards for Particulate Matter)
- C-AR285 (TxDOT Memorandum with subject Inquiry on Potential for CAP-EX Supplemental)
- Peer-reviewed literature cited later in this report
- EPA 2007 memorandum with subject "Reflecting the Revised PM_{2.5} National Ambient Air Quality Standard in NEPA Evaluations"
- Other selected content related to air quality on the U.S. EPA website (www.epa.gov)

As addressed in this report, in my professional opinion, a supplemental EIS is required for the Project under NEPA considering EPA's new annual PM_{2.5} NAAQS and associated scientific basis and because the Project is likely to cause significant adverse PM_{2.5} impacts. In my professional opinion, TxDOT has unreasonably claimed that its pre-project status of being below the U.S. EPA NAAQS under the Clean Air Act (CAA) somehow excused evaluation of PM_{2.5} impacts under NEPA. Yet now, despite being aware that Austin's current air quality exceeds the new PM_{2.5} NAAQS, TxDOT refuses to consider this as a reason to supplement its EIS based upon the new NAAQS.

My opinions in this report are based upon my education and background, experience, and materials referenced herein.

2.0 Overview

2.1 Determination of the Appropriate Level of NEPA Air Quality Analysis

The National Environmental Policy Act (NEPA) requires the Federal Government, in cooperation with state and local governments and other concerned public and private organizations, to assess the anticipated environmental impacts of proposed agency actions prior to making decisions⁵. The goal of the analysis of effects of various project alternatives, including the No Action and Build alternatives, is to support informed decision-making and transparency on the selection of an alternative.

In the context of air quality, this NEPA process requires an analysis of the potential effects of harmful air pollution anticipated from a proposed project and alternatives to the proposed project. The expected rigor of analysis is much higher for an EIS compared to other NEPA reviews (EA and categorical exclusions) because the decision to prepare an EIS is made by the lead agency only when significant impacts are anticipated from a project. To determine which air pollutants should be included in a NEPA EIS analysis and how they should be addressed, NEPA professionals consider, at a minimum, the following factors:

- The type of project and air pollutants released during the proposed project and alternatives
- Current scientific information
- Current conditions in the affected environment
- Comments by the public or agencies

2.2 Type of Project and Air Pollutants

As part of the air quality analysis for an EIS, first the air emission sources anticipated due to the Project are identified along with the types of air pollutants anticipated to be released. Highway projects have different types of air emission

⁵ 42 U.S.C. §§ 4321-4347

sources such as mobile sources, stationary sources, and fugitive sources. Mobile emission sources may be on-road (e.g., highway motor vehicles) or off-road sources (e.g., construction vehicles). A stationary source is any structure or facility which emits an air pollutant (e.g., a diesel generator). Fugitive source emissions are those that do not pass through a stack or other equivalent opening and instead are released directly to the air. Emissions from these sources include criteria air pollutants, hazardous air pollutants (also referred to as air toxics) and greenhouse gases (GHG). Highway projects result in potentially large emissions and concentrations of criteria pollutants and precursors such as carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC), other air toxics, and PM_{2.5} (both emitted directly and formed in the air from NO_x and VOC released from vehicles⁶).

PM_{2.5} are fine inhalable particles with an aerodynamic diameter⁷ less than 2.5 micrometers. This is approximately one-thirtieth the width of a human hair (Figure 1). PM_{2.5} can stay in the air for days or weeks and can travel hundreds of miles.

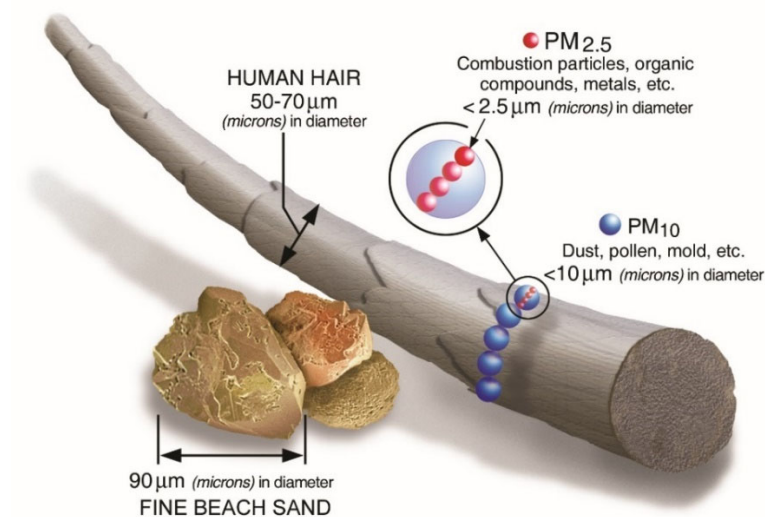


Figure 1. Particulate matter overview (figure source: <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics>)

⁶ PM_{2.5} may also be formed in the air from sulfur dioxide (SO₂) in vehicle tailpipe emissions, but SO₂ has reduced considerably with the use of cleaner burning fuels

⁷ Aerodynamic diameter is the diameter of a spherical particle of unit density having the same aerodynamic properties as the particle in question

Highway projects are a large source of PM_{2.5} pollution from operations and construction activities. These particles originate from the combustion of fuel in transportation, including cars, trucks, and buses, and are released directly or formed in atmosphere from vehicle emissions. When gasoline or diesel is burned, it releases a mixture of pollutants, including soot, metals, other inorganic compounds, and organic compounds, which contribute to PM_{2.5} levels in the air. PM_{2.5} is also formed in the atmosphere from tailpipe exhaust emissions of NO_x and VOC gases. Additionally, non-exhaust vehicle sources such as tire and brake wear as well as the resuspension of road dust caused by vehicle movement (resuspended road dust) contribute to PM_{2.5} emissions. Construction activities also contribute to PM_{2.5} through fugitive dust or vehicle emissions of PM_{2.5} or PM_{2.5} formed in the air from NO_x and VOC from on-road vehicles and off-road vehicles/equipment such as dozers and haul trucks.

As discussed below, the increase in air pollution from transportation due to PM_{2.5} and other pollutants near highways and other roadways is well documented in the peer-reviewed literature and regulatory agency reports.

A 2019 TxDOT report⁸ presents a review of near-road monitor concentrations and the potential contribution from major roadways⁹ across the country. The report notes that major roadways are an important emission source of particulate pollution, through vehicle exhaust, brake and tire wear, and re-suspended road dust, and that PM_{2.5} mass has been shown to be higher next to a major roadway than at other nearby locations, although near-road concentrations are typically dominated by urban background¹⁰. The 2019 TxDOT report notes that the Austin monitor near North I-35 shows a mean PM_{2.5} increment (increase) of 0.92 µg/m³ (or 9.7% of the total PM_{2.5}) due to the highway. The report also cites as an example a study of three near-road monitoring stations sited between 6 and 15 meters from

⁸ C-AR032. Texas Department of Transportation (2019). Near-Road Particulate Pollution: PM_{2.5}, Black Carbon, and Ultrafine Particles at U.S. Near-Road Monitoring Sites. Analysis of near-road PM_{2.5}, black carbon, and ultrafine particle monitor concentrations and the potential contribution from roadways. TxDOT Environmental Affairs Division. 200.05.GUI. December.

⁹ The roadways assessed included a combination of interstate highways, state highways and other major roads

¹⁰ Urban background is the concentration due to a combination of regional sources and diffuse urban emissions

their target roadway in Toronto and Vancouver, Canada, that estimated that on-road emissions contributed between 15% and 35% of near-road PM_{2.5}.

Gantt et al. (2021)¹¹ with the U.S. EPA assessed fine particulate matter near major highways in different regions of the U.S. using data from the National Near-Road Monitoring Network. They note that with more than 11 million people in the U.S. living within 150 meters of a major highway, there is a concern about the potential health impacts from air pollutants emitted from cars, trucks, and other vehicles. Using spatial interpolation to determine the near-road concentration increments of PM_{2.5} (the difference between concentrations measured by the roads and those measured at nearby sites), they estimated that the national average PM_{2.5} increment near highways was 1.0 µg/m³. They note that studies show that concentrations of PM_{2.5} are higher in cases when the site has conducive meteorological conditions (downwind of the road, low wind speed, and little atmospheric mixing) during periods of high traffic volume.

Jhun et al. (2019)¹² report that distance to major roadways is a proxy for long-term exposure to traffic-related air pollution as well as acute exposures, given that individuals with high long-term residential traffic exposures are also more likely to have high acute exposures. Using near-road air quality monitoring data across the U.S., Seagram et al. (2019)¹³ note that air pollutant concentrations are often higher near major roadways than in the surrounding environment owing to the proximity to emissions from on-road mobile sources and by analyzing monitoring data concluded that near-road sites showed a mean PM_{2.5} increment across 30 sites of +0.6 to +1.1 µg/m³ (or 6–10% of the average PM_{2.5}).

¹¹ Gantt, B., Owen, R. C., & Watkins, N., (2021). Characterizing nitrogen oxides and fine particulate matter near major highways in the United States using the National Near-Road Monitoring Network. *Environmental Science & Technology*, 55(5), 2831–2838. <https://doi.org/10.1021/acs.est.0c05851>

¹² Jhun, I., Kim, J., Cho, B., Gold, D. R., Schwartz, J., Coull, B. A., Zanobetti, A., Rice, M. B., Mittleman, M. A., Garshick, E., Vokonas, P., Bind, M.-A., Wilker, E. H., Dominici, F., Suh, H., & Koutrakis, P., 2019. Synthesis of Harvard EPA Center studies on traffic-related particulate pollution and cardiovascular outcomes in the Greater Boston Area. *Journal of the Air & Waste Management Association*, 69(8), 900–917. <https://doi.org/10.1080/10962247.2019.1596994>

¹³ Seagram, A. F., Brown, S. G., Huang, S.-M., Landsberg, K., & Eisinger, D. S. (2019). National assessment of near-road air quality in 2016: Multi-year pollutant trends and estimation of near-road PM_{2.5} increment. *Transportation Research Record*, 2673(2), 161–171. <https://doi.org/10.1177/0361198119825538z>

As discussed below, non-exhaust emissions of PM_{2.5} from vehicles due to tire and brake wear and resuspended dust are becoming an increasingly larger fraction and important component of vehicle emission impacts as tailpipe emissions decrease due to regulations and technology transition.

Using near-road air pollution monitoring measurements in Fort Worth, Texas, Askariyeh and co-researchers at Texas A&M University¹⁴ concluded that resuspended dust increases near-road PM_{2.5} concentrations along a highway in Texas by 16–19%. They also highlight that resuspended dust cannot be controlled by new technologies or new vehicle emission standards and its relative importance is becoming larger with the introduction of electric vehicles, especially in cities.

While all vehicles exhibit some amount of tire and brake wear and consequent PM emissions, this feature is much more pronounced for electric vehicles (EVs). A key factor influencing these emissions is vehicle weight. EVs on average are 24% heavier than gasoline and diesel engine vehicles due to their heavier batteries which leads to increased tire and brake wear (Timmers and Achten, 2016; Requia et al., 2018)¹⁵. Brake wear rates primarily depend on the material composition of the brakes and the mass of the vehicle that needs to be stopped (Timmers and Achten, 2018)¹⁶. Since heavier vehicles possess greater inertia, they require more braking force, resulting in increased brake wear leading to increased PM emissions¹⁶. Wang et al. (2023)¹⁷ analyzed non-tailpipe emission impacts on ambient PM_{2.5} near a California highway using PM_{2.5} air concentration

¹⁴ Askariyeh, M. H., Venugopal, M., Khreis, H., Birt, A., & Zietsman, J. (2020). Near-road traffic-related air pollution: Resuspended PM_{2.5} from highways and arterials. *International Journal of Environmental Research and Public Health*, 17(8), 2851. <https://doi.org/10.3390/ijerph17082851>. Last downloaded January 2, 2025.

¹⁵ Timmers, V.R.J.H., Achten, P.A.J., 2016. Non-exhaust PM emissions from electric vehicles. *Atmos. Environ.* 134, 10–17. <https://doi.org/10.1016/j.atmosenv.2016.03.017>

Requia, W.J., Mohamed, M., Higgins, C.D., Arain, A., Ferguson, M., 2018 How clean are electric vehicles? Evidence-based review of the effects of electric mobility on air pollutants, greenhouse gas emissions and human health, *Atmospheric Environment*, doi: 10.1016/j.atmosenv.2018.04.040.7

¹⁶ Timmers, V.R.J.H. and Achten, P.A.J., 2018. Non-Exhaust PM emissions from battery electric vehicles. In: *Non-Exhaust Emissions*, pp. 261-287. Elsevier. <https://doi.org/10.1016/B978-0-12-811770-5.00012-1>

¹⁷ Wang, X.; Gronstal, S.; Lopez, B.; Jung, H.; Chen, L. W. A.; Wu, G.; Ho, S. S. H.; Chow, J. C.; Watson, J. G.; Yao, Q.; Yoon, S. Evidence of Non-Tailpipe Emission Contributions to PM_{2.5} and PM₁₀ near Southern California Highways. *Environ. Pollut.* 2023, 317, 120691.

measurements and concluded that tire tread particles contributed up to 8% of total PM_{2.5} mass.

Because the Project is a highway expansion project involving construction and operational phases from which PM_{2.5} and PM_{2.5} precursors will be emitted, had I been involved in the Project, I would have analyzed PM_{2.5} impacts. In my 25 years' experience in environmental practice, it is common practice to analyze PM_{2.5} emissions and precursors from vehicles when vehicle sources are present.

2.3 Current Scientific Information

Based on my education, experience, and background, I am aware that PM_{2.5} is regularly analyzed under NEPA as the "best available science" (or currently available scientific evidence) shows that exposure to particulate matter is associated with severe negative health impacts, including fatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function and premature death¹⁸. The small size of PM_{2.5} particles allows them to penetrate deep into the lungs and even enter the bloodstream, posing serious health risks as discussed further below.

The U.S. EPA's Integrated Science Assessment (ISA) for PM (dated December 2019)¹⁸ cites extensive scientific literature on the adverse health impacts of PM_{2.5} as part of the rule making for the PM_{2.5} NAAQS.

What the literature cited in the ISA (reflecting the scientific literature on the subject) shows is that short-term exposure to PM_{2.5} is associated with respiratory-related emergency department visits, hospital admissions, and respiratory mortality, and asthma, respiratory infections, chronic obstructive pulmonary disease (COPD), and combined respiratory-related diseases. Long-term exposure to PM_{2.5} is associated with impaired lung function growth in children, accelerated lung function decline in adults, and increased respiratory mortality. The U.S. EPA also notes that long-term PM_{2.5} exposure is likely to be causal for cancer, particularly

¹⁸ <https://assessments.epa.gov/isa/document/&deid=347534>;
https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=539935

lung cancer, based on epidemiologic and mechanistic studies. The U.S. EPA notes that children, older adults, and individuals with pre-existing respiratory or cardiovascular conditions are particularly vulnerable to the health effects of PM_{2.5}.

In 2021, the U.S. EPA announced¹⁹ that it would reconsider the NAAQS for PM_{2.5} which was last revised in 2012. EPA's reconsideration was "because available scientific evidence and technical information indicate that the current standards may not be adequate to protect public health and welfare, as required by the Clean Air Act."

In 2022, the U.S. EPA published a supplement to the ISA²⁰ that provides new health effects evidence on the causal relationship between PM_{2.5} exposure and cardiovascular effects and mortality and reinforces the importance of addressing health risks at lower PM_{2.5} concentrations. The supplement reports that new studies indicate an association between PM_{2.5} concentrations and heart disease, heart failure, stroke, and atherosclerosis, and an association with mortality at lower PM_{2.5} concentrations.

The U.S. EPA relies on the best available science to guide any changes to the NAAQS. Based on the above scientific evidence, the U.S. EPA proposed a strengthening of the annual PM_{2.5} NAAQS down from 12 µg/m³ to a range of 9 to 10 µg/m³ on January 6, 2023²¹. EPA announced that it finalized the standards on February 7, 2024²², setting the NAAQS at 9.0 µg/m³.

Not only does the EPA rely on the best available science to guide, but it is also the industry standard²³ to rely on such science, at a minimum, for the purpose of

¹⁹ C-AR267. EPA to Reexamine Health Standards for Harmful Soot that Previous Administration Left Unchanged.

²⁰ https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=544706

²¹ <https://www.epa.gov/newsreleases/epa-proposes-strengthen-air-quality-standards-protect-public-harmful-effects-soot>

²² C-AR283 (89 FR 16202); <https://www.epa.gov/newsreleases/epa-finalizes-stronger-standards-harmful-soot-pollution-significantly-increasing>

²³ Industry standard is defined here to mean the criteria followed by environmental professionals relating to the standard functioning and carrying out of operations when conducting NEPA analysis

determining the air analysis conducted pursuant to NEPA. “Best available science” is the industry standard for NEPA professionals.

The Project is one involving transportation, from which PM_{2.5} and its precursor emissions are always associated, and there was evidence available that showed the adverse health impacts of PM_{2.5} were impactful at levels much lower than the 12 µg/m³ NAAQS in effect before February 2024. Based on my education, experience, and background, it is my opinion that TxDOT acted unreasonably in ignoring the best available science, evidenced by the 2022 supplemental ISA, in evaluating impacts of the Project and alternatives on PM_{2.5} pollution.

2.4 Failure to Establish Current Conditions in the Affected Environment

An EIS is supposed to analyze how a proposed action and alternatives to a preferred action would affect the environment, such as air, if any of the alternatives is implemented, typically comparing the same to a no action (No Build) alternative. Current conditions or levels of air pollutants as discussed in the Affected Environment section of the EIS provide context for a comparison between the proposed action, action alternatives and a No Build alternative. Here, TxDOT did not establish the current, pre-project levels of PM_{2.5} in the EIS. It could have done so by referring to PM_{2.5} air concentrations in Austin as measured at monitoring locations that are part of the EPA Air Quality System (AQS)²⁴; these measurements are addressed below in Section 4.0. In my professional opinion, the failure to quantify and disclose current concentrations was not reasonable or normal. The industry standard is to quantify and disclose current ambient PM_{2.5} data from the AQS (or similar monitoring network) to understand the quality of the environment (the magnitude of current air concentrations relative to the current and proposed NAAQS) that would be affected by the proposed action and alternatives.

²⁴ <https://www.epa.gov/aqs>

2.5 Methods used Conventionally for PM_{2.5} Analysis in an EIS

The first step in the PM_{2.5} analysis in the air quality impact assessment for an EIS is establishing and disclosing the current pollutant level in the affected human environment. Current air concentrations that are close to or higher than a proposed air standard would call for more scrutiny of the proposed action and alternatives. The second step is the identification of emission sources; this information is available from the detailed description of the proposed action/alternatives and plot plans and is collected routinely during any EIS. A project may include mobile, stationary, and fugitive sources of air pollutants released during the construction and operational/maintenance phases. The next step is the compilation or calculation of required parameters such as annual average daily traffic, other traffic data, time period of analysis, road segment lengths, fuel type and consumption, speed limits, displaced and/or induced traffic, vehicle type, model years, vehicle miles traveled (VMT), construction activities and schedule, equipment usage, etc. Most of these data are also compiled when a CO or mobile source air toxics (MSAT) analysis is performed, and, thus, TxDOT had information on these parameters as it conducted a quantitative CO and quantitative MSAT analysis for the EIS.

The U.S. EPA Motor Vehicle Emissions Simulator (MOVES model)²⁵ is recommended by EPA to estimate emissions from on-road (highway) and off-road mobile emissions. MOVES provides modeled emissions estimates for criteria pollutants and precursors, air toxics and GHGs. These include²⁶ PM_{2.5}, PM₁₀, CO, NO_x, VOC, total hydrocarbons, elemental carbon (EC), sulfur dioxide (SO₂), ammonia, benzene, ethanol, 1,3 butadiene, formaldehyde, acetaldehyde, acrolein, polycyclic aromatic hydrocarbons, metals, dioxins, furans, and carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). MOVES calculates emissions for vehicle running, start, extended idle, brake wear, tire wear, evaporative fuel vapor venting, evaporative fuel leaks, and refueling vapor and spillage.

²⁵ <https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves>

²⁶ <https://www.epa.gov/system/files/documents/2024-11/420r24011.pdf>

When preparing an EIS, emissions from stationary sources, if any, and fugitive dust or resuspended dust are usually calculated using source parameters and data from the U.S. EPA AP-42 database^{27, 28} and other data from EPA.

The emissions of vehicle PM_{2.5} and the main vehicle-related PM_{2.5} precursors (i.e., NOx and VOC) due to highway vehicles and construction equipment and vehicles and other project sources can thus be anticipated, modeled, and quantified, and subsequently compared across alternatives to understand the potential additional burden due to the project alternatives and inform the EIS decision.

Based on my education, experience, and background, it is my opinion that TxDOT acted unreasonably and contrary to industry standard in not calculating, disclosing, and analyzing emissions of PM_{2.5} and its precursors (NOx and VOC) anticipated from the proposed project and alternatives during the NEPA analysis by using the MOVES model or similar models.

²⁷ <https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors-stationary-sources>

²⁸ <https://www3.epa.gov/ttnchie1/ap42/ch13/final/c13s02.pdf>

3.0 NEPA Analysis and Comments for the I-35 Project

The following section presents, in the context of the information discussed above, some comments on the environmental effects analysis performed in the EIS for the proposed I-35 Capital Express Highway expansion in downtown Austin.

3.1 Air Quality Analysis by TxDOT

To assess Project operational impacts, TxDOT performed a carbon monoxide (CO) traffic air quality analysis using CO emission rates and the CAL3QHC dispersion model to assess whether the proposed project would be anticipated to adversely affect local air quality by contributing to CO levels that exceed the 1-hour or 8-hour CO NAAQS. The CO emission rates were derived²⁹ from the U.S. EPA MOVES model, gathered from the TxDOT Emission Rates Lookup Tables. The CO analysis was performed for the No Build alternative, Build Alternative 2 and the Modified Build Alternative 3.

TxDOT also performed a quantitative analysis of nine MSAT (1,3-butadiene, acrolein, acetaldehyde, benzene, diesel particulate matter (DPM), ethylbenzene, formaldehyde, naphthalene, and polycyclic organic matter) emissions during operation. They conducted the analysis for the preferred alternative using emission rate tables from the TxDOT air quality toolkit and data from the MOVES model (MOVES3 version).

Anticipated emissions impacts of the proposed project and alternatives for PM_{2.5} and PM₁₀ were not quantified in the NEPA analysis. The reason provided for failing to conduct any quantitative analysis of PM_{2.5} whatsoever under NEPA is that the Clean Air Act's transportation conformity rules do not apply because the area was pre-

²⁹ C-AR220. Appendix P. Air Quality. Final Environmental Impact Statement and Record of Decision. I-35 Capital Express Central Project from US 290 East to US 290 West/SH 71. August 2023.

project designated in attainment or unclassifiable for all criteria pollutants, including PM_{2.5}.

Regarding construction emissions, TxDOT noted that construction activities may result in temporary increases in PM and MSAT emissions and stated that they did not anticipate construction emissions would have any significant impact on air quality because of the “temporary and transient nature” of construction, the use of fugitive dust control measures, the Texas Emissions Reduction Plan (TERP), and compliance with applicable regulatory requirements. However, as discussed below in section 3.2, a more robust construction analysis was warranted as a long time period of roughly 8 years of construction is not “transient”.

3.2 Comments by Public and Participating Agencies

Comments by the public and participating agencies are given serious consideration in NEPA air quality analysis to meet NEPA expectations for disclosure and stakeholder participation.

Concerns over construction dust impacts were raised in several comments during scoping and the public DEIS. However, the FEIS only provides³⁰ a limited description of project construction PM dust impacts. The FEIS does not specify what dust suppression measures would be employed or how they would be enforced. Construction on I-35 is expected to last approximately 8 to 10 years³¹; this lengthy period is not “transient” as noted by TxDOT. Given the lengthy construction period, a more robust EIS analysis was warranted that provided details on the dust control measures that would be used to mitigate the effect of dust emissions of PM_{2.5} and PM₁₀ and protect nearby residents from harmful exposure from the proposed construction activities over several years.

³⁰ C-AR202. Final Environmental Impact Statement and Record of Decision. I-35 Capital Express Central Project from US 290 East to US 290 West/SH 71. Section 3.12.4. August 2023.

³¹ C-AR202. Final Environmental Impact Statement and Record of Decision. I-35 Capital Express Central Project from US 290 East to US 290 West/SH 71. Section 3.17.1. August 2023. Note that the TxDOT response to public comment #178 in C-AR211 indicates that construction would last approximately six years, also a long period.

The need for a detailed air quality analysis in the EIS was highlighted during the scoping comments. For example, L. Olinde, who lives near I-35, commented³² that that there are “many daycares along this stretch of I-35 as well as playgrounds, elderly residents, covid patients will long term breathing complications, outpatient clinics, and hospitals”. T. Thomas commented³³ that “pollution (especially particulate pollution from tires) from IH-35 fouls our city.”

In response to DEIS comments from A. Baratz³⁴, TxDOT stated that

Tire wear is an issue of concern associated with PM and, as such, is addressed through the Clean Air Act (CAA) process of conformity for PM constituents. Since the project is an attainment or unclassifiable area for PM, the applicable CAA regulations do not recommend additional analysis. FHWA NEPA’s guidance also does not recommend additional PM analysis beyond the CAA regulatory requirements.

Travis County, a participating agency, commented³⁵ on the DEIS, stating: “The expected proliferation of electric vehicles, as outlined in the draft EIS, are not guaranteed to reduce overall pollution levels from traffic. Pollution from tire friction and wear, for example, may worsen with an increase in EVs due to increase in vehicle weight from electric batteries.”

Considering that PM_{2.5} emissions from tire and brake wear would increase with the transition to EVs, a quantitative discussion was warranted in the FEIS on the expected change in the total tailpipe and non-tailpipe emissions of PM_{2.5} due to the proposed project to inform decision-making on the appropriate alternative.

As noted by Travis County, “PM_{2.5} is a significant public health threat. Children and the elderly are especially vulnerable. This study should specifically analyze existing and future PM_{2.5} at schools and elder care facilities within 2 miles of I35”. It is reasonable that the FEIS should have included such an analysis due to the high PM_{2.5} concentrations in Austin (as discussed later in Section 4). Every day, more

³² C-AR062 pdf page 104

³³ C-AR062 pdf page 1514

³⁴ Comment #18 in C-AR211

³⁵ Comment #674 in C-AR211

than 200,000 vehicles travel on I-35 within the project area³⁶, so even a 1% increase in the number of vehicles would result in 3000 more vehicles per day which would further increase PM_{2.5} pollution from a combination of tailpipe emissions (from gasoline/diesel vehicles) and non-tailpipe emissions (from electric vehicles) in the area.

During the DEIS public comment process, the City of Austin, a participating agency, expressed concerns on the limited PM effects analysis performed in the DEIS. For example, the City stated³⁷ that its top priority and “near non-attainment” NAAQS compliance concerns are for ozone and particulate matter, but that these priority pollutants were not modeled. The city requested additional “impact analysis for criteria pollutants with a focus on PM and ozone to ensure we remain in attainment [*under CAA*] for all scenarios [*NEPA alternatives*]” (text in italics added). The final EIS by TxDOT does not include the analysis requested by the City of Austin. In my experience, at a minimum, TxDOT should have quantified anticipated PM_{2.5} and precursor emissions (NO_x and VOC) from the vehicles operating on the expanded highway to understand the anticipated change due to the proposed project and alternatives.

The City of Austin also submitted comments requesting monitoring and mitigation measures to track and minimize particulate impacts³⁷, for example, requesting a health impact assessment (similar to one done for another highway project in Houston^{37, 38}) and air quality monitors at parks, schools, and playgrounds during and after project completion, as well as funding for HEPA filters to improve indoor air quality for residents within 500 feet of the highway.

³⁶ C-AR211 TxDOT Response to Comment #3

³⁷ C-AR217 pdf page 138

³⁸ A copy of the Houston I-45 expansion health impact assessment (HIA) referenced by the City of Houston may be found at <https://airalliancehouston.org/wp-content/uploads/2019/09/HIA-Report-final-06-10-19.pdf>. This HIA was developed to quantify the I-45 expansion project’s potential positive and negative health effects. To monitor and mitigate negative health impacts, the HIA recommended that TxDOT provide funding for the installation of air monitors at sensitive receptors like schools, parks, and playgrounds during and after project completion, and funding for the ongoing installation of HEPA filters within buildings with sensitive occupants within 500 feet of the highway.

Based on my education, experience, and background, my opinion is that TxDOT acted unreasonably and inconsistent with industry standards in not fully addressing comments from the public and participating agencies. If I had been working on the Project, I would have analyzed vehicle PM_{2.5} emissions quantitatively from the proposed project and alternatives at a minimum.

3.3 The Clean Air Act and NEPA

As TxDOT notes in Section 3.12 of the FEIS, "In addition to the CAA transportation conformity requirements for highway projects, NEPA establishes procedural requirements for major federal actions significantly affecting the quality of the human environment. However, rather than treat the CAA and NEPA as distinct laws TxDOT is conflating NEPA requirements with those of the conformity regulations under the CAA to justify its decision not to analyze PM_{2.5}.

Pursuant to the Clean Air Act, when the U.S. EPA finds an area is unable to meet the air quality standards in the NAAQS, the area is designated as a nonattainment area. This requires the agency to make a conformity evaluation under the CAA³⁹. The conformity requirements of the CAA do not apply to areas in attainment of the NAAQS.

However, this does not mean when conducting a NEPA analysis, a new project cannot be anticipated to cause significant air quality impacts or anticipated to cause the area to be in nonattainment in the future. In this case, the Project will increase traffic on I-35 and during construction and operation, emissions of PM_{2.5} and precursors will be generated closer to residents, pedestrians, and bicyclists. Relying upon current attainment to avoid analysis of future attainment without providing any quantitative evidence that the Project will not increase total emissions of PM is not reasonable or consistent with industry standards.

NEPA is designed to address environmental effects (such as air quality) regardless of an area's classification under the CAA. NEPA's applicability is not restricted to

³⁹ A conformity evaluation is also required when an area is in maintenance, i.e., previously in nonattainment and has since improved its air quality to meet the NAAQS.

nonattainment areas. Moreover, NEPA considers the impacts of proposed actions and CAA attainment status refers to present conditions.

Based on my education, experience, and background, my opinion is that it was unreasonable and inconsistent with NEPA's requirements for TxDOT to ignore, based upon the present CAA attainment status, quantifying the *anticipated* PM_{2.5} impacts to air quality for purposes of a NEPA analysis as well as comments by the public and participating agencies.

Considering that (i) the proposed project would release a pollutant of major health concern, i.e., PM_{2.5}, (ii) it was completely foreseeable that EPA's anticipated proposed strengthening of the PM_{2.5} standard would bring the area of the project into non-attainment during the future construction and operation of the expanded highway, (iii) current PM_{2.5} levels near the proposed project are higher than the new NAAQS, and (iv) the city that is directly impacted (here, Austin) expressed concerns about "near non-attainment", in my experience, it would be expected that the final EIS would disclose the current conditions as well as the anticipated PM_{2.5} effects from the proposed project and alternatives.

4.0 Supplemental EIS

According to Council on Environmental Quality (CEQ) regulations at 40 CFR 1502.9, agencies shall prepare supplements to either draft or final environmental impact statements if a major Federal action is incomplete or ongoing, and there are substantial new circumstances or information about the significance of adverse effects that bear on the analysis. According to FHWA regulations at 23 CFR §771.130, an EIS must be supplemented whenever the Administration determines that new information or circumstances relevant to environmental concerns and bearing on the proposed action or its impacts would result in significant environmental impacts not evaluated in the EIS.

When substantial new information on air quality effects becomes available later, the lead agency is required to incorporate such information through the preparation of a supplemental EIS⁴⁰. While an agency need not prepare a supplement to an EIS every time new information comes to light after the EIS is finalized, NEPA does require that agencies take a “hard look” at the environmental effects of their action, even after a proposal has received initial approval⁴¹. The Supreme Court has explained⁴¹ that in determining whether supplemental analysis is required, the value of the new information is important. “In this respect the decision to prepare a supplemental EIS is similar to the decision whether to prepare an EIS in the first instance: if there remains “major Federal actio[n]” to occur, and if the new information is sufficient to show that the remaining action will “affec[t] the quality of the human environment” in a significant manner or to a significant extent not already considered, a supplemental EIS must be prepared”.

On February 7, 2024, the U.S. EPA announced⁴² that it had finalized the rule on the “Reconsideration of the National Ambient Air Quality Standards for Particulate

⁴⁰ <https://www.ecfr.gov/current/title-40/chapter-V/subchapter-A/part-1502/section-1502.9>

⁴¹ Marsh v. Oregon Natural Resources Defense Council, 490 U.S. 360, 371 (1989)

⁴² <https://www.epa.gov/pm-pollution/final-reconsideration-national-ambient-air-quality-standards-particulate-matter-pm>

Matter” and was lowering the annual NAAQS for PM_{2.5} from 12 to 9 µg/m³. In the final rule, the U.S. EPA stated⁴³:

In June 2021, the Agency announced its decision to reconsider the 2020 PM NAAQS final action. The U.S. EPA decided to reconsider the December 2020 decision because the available scientific evidence and technical information indicated that the current standards may not be adequate to protect public health and welfare, as required by the Clean Air Act. The U.S. EPA noted that the 2020 PA concluded that the scientific evidence and information called into question the adequacy of the primary PM_{2.5} standards and supported consideration of revising the level of the primary annual PM_{2.5} standard to below the current level of 12.0 µg/m³. ...

The final decisions presented in this document on the primary PM_{2.5} standards have been informed by key aspects of the available health effects evidence and conclusions contained in the 2019 ISA and ISA Supplement, quantitative exposure/risk analyses and policy evaluations presented in the 2022 PA, advice from the CASAC and public comment received as part of this reconsideration. The health effects evidence newly available in this reconsideration, in conjunction with the full body of evidence critically evaluated in the 2019 ISA, supports a causal relationship between long- and short-term exposures and mortality and cardiovascular effects, and the evidence supports a likely to be a causal relationship between long-term exposures and respiratory effects, nervous system effects, and cancer. The longstanding evidence base, including animal toxicological studies, controlled human exposure studies, and epidemiologic studies, reaffirms, and in some cases strengthens, the conclusions from past reviews regarding the health effects of PM_{2.5} exposures. Epidemiologic studies available in this reconsideration demonstrate generally positive, and often statistically significant, PM_{2.5} health effect associations. Such studies report associations between estimated PM_{2.5} exposures and non-accidental, cardiovascular, or respiratory mortality; cardiovascular or respiratory hospitalizations or emergency room visits; and other mortality/morbidity outcomes (e.g., lung

⁴³ C-AR283 (89 FR 16202); <https://www.epa.gov/newsreleases/epa-finalizes-stronger-standards-harmful-soot-pollution-significantly-increasing>

cancer mortality or incidence, asthma development). The scientific evidence available in this reconsideration, as evaluated in the 2019 ISA and ISA Supplement, includes a number of epidemiologic studies that use various methods to characterize exposure to PM_{2.5} (e.g., ground-based monitors and hybrid modeling approaches) and to evaluate associations between health effects and lower ambient PM_{2.5} concentrations. There are a number of recent epidemiologic studies that use varying study designs that reduce uncertainties related to confounding and exposure measurement error. The results of these analyses provide further support for the robustness of associations between PM_{2.5} exposures and mortality and morbidity. Moreover, the Administrator notes that recent epidemiologic studies strengthen support for health effect associations at lower PM_{2.5} concentrations, with these new studies finding positive and significant associations when assessing exposure in locations and time periods with lower annual mean and 25th percentile concentrations than those evaluated in epidemiologic studies available at the time of previous reviews. Additionally, the experimental evidence (i.e., animal toxicological and controlled human exposure studies) strengthens the coherence of effects across scientific disciplines and provides additional support for potential biological pathways through which PM_{2.5} exposures could lead to the overt population-level outcomes reported in epidemiologic studies for the health effect categories for which a causal relationship (i.e., short- and long-term PM_{2.5} exposure and mortality and cardiovascular effects) or likely to be causal relationship (i.e., short- and long-term PM_{2.5} exposure and respiratory effects; and long-term PM_{2.5} exposure and nervous system effects and cancer) was concluded.

The available evidence in the 2019 ISA continues to provide support for factors that may contribute to increased risk of PM_{2.5}-related health effects including lifestage (children and older adults), pre-existing diseases (cardiovascular disease and respiratory disease), race/ethnicity, and socioeconomic status. For example, the 2019 ISA and ISA Supplement conclude that there is strong evidence that Black and Hispanic populations, on average, experience higher PM_{2.5} exposures and PM_{2.5}-related health risks than non-Hispanic White populations. In addition, studies evaluated in the 2019 ISA and ISA Supplement also provide evidence indicating that

communities with lower socioeconomic status (SES), as assessed in epidemiologic studies using indicators of SES including income and educational attainment are, on average, exposed to higher concentrations of PM_{2.5} compared to higher SES communities. The quantitative risk assessment, as well as policy considerations in the 2022 PA, also inform the final decisions on the primary PM_{2.5} standards. The risk assessment in this reconsideration focuses on all-cause or nonaccidental mortality associated with long- and short-term PM_{2.5} exposures. The primary analyses focus on exposure and risk associated with air quality that might occur in an area under air quality conditions that just meet the current and potential alternative standards. The risk assessment estimates that the current primary PM_{2.5} standards could allow a substantial number of PM_{2.5}-associated premature deaths in the United States, and that public health improvements would be associated with just meeting all of the alternative (more stringent) annual and 24-hour standard levels modeled. Additionally, the results of the risk assessment suggest that for most of the U.S., the annual standard is the controlling standard and that revision to that standard has the most potential to reduce PM_{2.5} exposure-related risk. ...

Based on the current evidence and quantitative information, as well as consideration of CASAC advice and public comments, the Administrator concludes that the current primary annual PM_{2.5} standard is not adequate to protect public health with an adequate margin of safety. The Administrator notes that the CASAC was unanimous in its advice on the 2021 draft PA regarding the need to revise the annual standard. In considering the appropriate level for a revised annual standard, the Administrator concludes that a standard set at a level of 9.0 µg/m³ reflects his judgment about placing the most weight on the strongest available evidence while appropriately weighing the uncertainties.

Original footnotes omitted.

Following a review of scientific information on the harmful effects of PM_{2.5} at concentrations lower than 12 µg/m³, the U.S. EPA proposed a strengthening of the annual PM_{2.5} NAAQS down from 12 µg/m³ to a range of 9 to 10 µg/m³ on January 6,

2023²¹. The U.S. EPA published the standard in the federal register on March 6, 2024⁴⁴, setting the NAAQS at 9.0 $\mu\text{g}/\text{m}^3$ based on scientific information indicating additional association between PM_{2.5} concentrations and heart disease, heart failure, stroke, and atherosclerosis, and an association with mortality at lower PM_{2.5} concentrations. During the rulemaking for the revision of the PM_{2.5} NAAQS, the U.S. EPA determined that strengthening the annual PM_{2.5} standard from 12 to 9 $\mu\text{g}/\text{m}^3$ prevents up to 4,500 premature deaths and 290,000 lost workdays, yielding up to \$46 billion in net health benefits in 2032²². These numbers indicate the enormity of the health damage that is caused by human exposure to PM_{2.5} in the air. None of this information was new on February 7, 2024, when the U.S. EPA first announced it was lowering the PM_{2.5} NAAQS. The 2019 ISA and 2022 ISA supplement were known to air quality professionals.

Previously, when the NAAQS for PM_{2.5} was revised, the U.S. EPA stated⁴⁵:

For proposed actions that have already completed the NEPA process, but have not yet been implemented, we recommend you consider the revised PM_{2.5} NAAQS to assess whether supplementation would be appropriate.

For conformity evaluations, the revised PM_{2.5} standard ... does not apply until one year after the effective date of nonattainment designations that consider that standard.

Thus, NEPA's requirement regarding *supplementation* is independent of CAA's *conformity* requirements. Therefore, in my professional opinion, it is not reasonable for TxDOT to avoid supplementation because conformity evaluations are not yet required.

PM_{2.5} air concentrations are measured at the Austin Webberville Road and Austin North Interstate 35 monitoring locations (Figure 2) (and other locations) that are

⁴⁴ C-AR283 (89 FR 16202); <https://www.epa.gov/newsreleases/epa-finalizes-stronger-standards-harmful-soot-pollution-significantly-increasing>

⁴⁵ U.S. EPA. 2007. Memorandum with subject: Reflecting the Revised PM_{2.5} National Ambient Air Quality Standard in NEPA Evaluations. Available at <https://www.epa.gov/sites/default/files/2014-08/documents/revised-pm2-5-naaqs-nepa-pg.pdf>. June 25.

part of the U.S. EPA AQS²⁴. Table 1 presents the annual PM_{2.5} concentration design values⁴⁶ over the past decade. The data from the Austin Webberville Road monitor indicate that while the PM_{2.5} design values have fluctuated up and down, all ten of the most recent design values exceed the current NAAQS of 9.0 µg/m³. The data from the Austin North Interstate 35 monitor demonstrate a steady increase in PM_{2.5} over 2019-2023, with the most recent design value at 9.6 µg/m³ for the 2021-2023 period. In particular, the annual concentration at this monitor jumped from approximately 9.5 to 10.5 µg/m³, likely partly due to construction work that was performed on North Interstate 35 in 2023. As of September 2024, the average 2024 concentration at this monitor was approximately 11 µg/m³, and thus even higher than prior years. Although a non-attainment designation will be formally issued only in 2026 by EPA, Austin currently exceeds 9.0 µg/m³ and has consistently exceeded this value for several years now and there is no margin for additional PM_{2.5} emissions contributions. The contributing emissions from the proposed highway expansion in Austin would further aggravate this problem. This was entirely predictable based on the information available to TxDOT at the time it conducted the NEPA analysis for the EIS for the Project, and in my professional opinion, it was unreasonable and inconsistent with industry standard to fail to consider the new NAAQS and associated PM_{2.5} impacts of the Project and alternatives.

⁴⁶ A design value is a statistic that summarizes measured air concentrations in the form of the NAAQS over a specific period (annual mean averaged over 3 years in the case of the annual PM_{2.5} NAAQS) to assess compliance with the NAAQS.

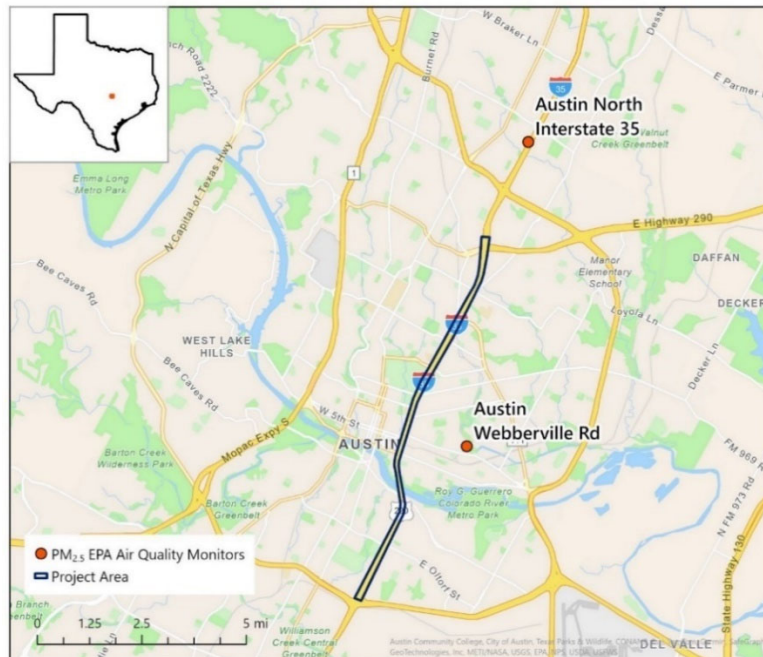


Figure 2. Locations of EPA Air Quality System monitoring stations near the project.

Table 1. Measured air concentrations (design values) of PM_{2.5} near the project.

AQS Site ID	Site Name	2012-2014 DV*	2013-2015 DV	2014-2016 DV	2015-2017 DV	2016-2018 DV	2017-2019 DV	2018-2020 DV	2019-2021 DV	2020-2022 DV	2021-2023 DV
484530021	Austin Webberville Rd	9.4	9.2	9.6	9.6	9.8	9.8	9.6	9.5	9.2	9.3
484531068	Austin North Interstate 35	-	-	-	-	-	9.3	9.3	9.2	9.3	9.6

DV, or design value, is the annual mean concentration, averaged over three consecutive years. Concentrations are in $\mu\text{g}/\text{m}^3$
Source of data: EPA Air Quality System at <https://www.epa.gov/air-trends/air-quality-design-values#report>

Based on my education, experience, and background, my opinion is that Austin exceeds the new annual PM_{2.5} air standard and the entirely foreseeable emissions of PM_{2.5} and its precursors from the Project are likely to have significant adverse effects by exacerbating the exceedance of the standards.

Based on my education, experience, and background, my opinion is that, given that TxDOT failed in the EIS to consider likely future PM_{2.5} non-attainment, the new PM_{2.5} rule by EPA constitutes substantial new circumstances or information. It is my opinion that PM_{2.5} should have been analyzed in the final EIS, but in light of the new NAAQS, it is even more critical that analysis now be done through supplementation.

In my professional opinion, non-exceedance of the NAAQS status at the time of the NEPA analysis should not have been used in the first place as the standard to determine whether to evaluate anticipated PM impacts of the Project under NEPA, but, having selected that as the relevant metric, it is unreasonable to decline to supplement based on a change in the NAAQS.

5.0 Summary of Opinion

In summary, based on my education, experience, and background, my opinion is that:

1. TxDOT acted unreasonably in failing to analyze the impacts of PM_{2.5} emissions from the Project and alternatives under NEPA because:
 - a. TxDOT did not consider fully the known, associated PM_{2.5} emissions from the Project.
 - b. TxDOT did not address fully the current levels of air pollutants.
 - c. TxDOT did not substantively address comments from the public and participating agencies (e.g., City of Austin, Travis County) with regards to PM_{2.5} impacts.
 - d. TxDOT did not use the MOVES program (or similar model) which the agency is familiar with, and which could have been used to address PM_{2.5} impacts.
 - e. TxDOT's conclusions regarding future PM_{2.5} levels are speculative as a result of its failure to rely on available data and perform quantitative analysis.
 - f. Having selected the CAA's NAAQS as the relevant standard, TxDOT reasonably failed to consider the anticipated changes to the NAAQS for PM_{2.5}. These anticipated changes would have been reasonably known to anyone analyzing air quality impacts of the Project and are based on scientific consensus that pre-date changes to the rules. This was particularly true as the agency received credible comments on the changes and chose to disregard those comments.
 - g. TxDOT improperly disregarded its obligations under NEPA to conduct an analysis of anticipated impacts of the Project and alternatives, resulting in an insufficient analysis of the impacts of PM_{2.5} and its precursors through misplaced reliance on Austin's designation as an attainment area under the CAA at the time of analysis. TxDOT did not take into account quantifiable anticipated impacts with Project or Project-alternative implementation.

2. TxDOT acted unreasonably in failing to conduct additional analysis and prepare a supplemental EIS after the U.S. EPA finalized a new NAAQS for PM_{2.5}, particularly since in its initial analysis it chose not to consider the possibility that the selected alternative would cause PM_{2.5} in excess of the NAAQS during operation. Austin currently exceeds the new annual PM_{2.5} NAAQS and emissions from the Project are likely to have significant adverse effects. It is not reasonable for TxDOT to have relied upon the CAA NAAQS to dismiss air quality concerns under NEPA, and then not conduct further analysis when that same standard, previously selected by TxDOT to avoid analysis, is now exceeded.

APPENDIX 1

CV of Krish Vijayaraghavan

KRISH VIJAYARAGHAVAN

Principal

Mr. Krish Vijayaraghavan has 25 years' experience in environmental practice and specializes in NEPA environmental reviews and air quality modeling. He has coordinated technical analyses for Environmental Impact Statements (EIS) & Environmental Assessments (EA) for surface transportation, aviation, mining, oil and gas, and renewable energy projects. Krish has expertise in air quality and greenhouse gas/climate change analysis, social cost of carbon calculations, and linkages with water quality and human health and ecological risk assessments. He has directed modeling studies of photochemical air pollution (ozone, secondary PM_{2.5}), sulfur and nitrogen oxides, volatile organic compounds, primary particulates, ammonia, PFAS and deposition of air toxics such as mercury, and analysis of methane, CO₂, N₂O, and environmental justice impacts. He has published on the relationship between air quality and climate change on a NASA grant. He has published over forty peer-reviewed research papers and co-authored two technical books. Krish has moderated NEPA professional training workshops in the U.S. to teach the fundamentals of Categorical Exclusions, EAs and EISs.



CONTACT INFORMATION

Krish Vijayaraghavan

kvijay@ramboll.com

+1 (415) 8990726

Ramboll

7250 Redwood Blvd, Ste 105

Novato, CA 94945

EDUCATION

MS, Environmental Engineering Georgia Institute of Technology, Atlanta

MS, Chemical Engineering University of Kansas, Lawrence

BTech, Chemical Engineering Indian Institute of Technology, Mumbai

SELECTED PROJECTS

NEPA EA for Dallas Fort Worth Airport Expansion

Technical advisor for the EA required under NEPA to assess the air quality, GHG and environmental justice impacts of a terminal expansion and other infrastructure upgrades at Dallas Fort Worth Airport, Texas. Services included preparation of the Affected Environment and Environmental Consequences sections of the EA and development of emissions inventories of criteria and hazardous air pollutants and greenhouse gases using ACEIT, MOVES and other data, assessment of environmental justice impacts and calculation of the social cost of carbon. A general conformity analysis was performed to assess construction and operation effects in the ozone nonattainment area. Led the description of the effects of climate change on the region and GHG mitigation measures required under CEQ NEPA regulations.

Air Quality Modeling for National Fuel Economy Standards pursuant to NHTSA NEPA EIS

The National Highway Transportation Safety Administration (NHTSA) prepared an Environmental Impact Statement (EIS) under NEPA to assess the nationwide environmental benefits of the Safer Affordable Fuel-Efficient (SAFE) Vehicle Rule and the revised Corporate Average Fuel Economy (CAFE) standards. The NHTSA requested support in assessing air quality impacts associated with the rule. Provided technical oversight for photochemical air quality modeling for light duty vehicles in the U.S. with Community Air Quality (CMAQ) model to assess and compare criteria air pollutant impacts among future year alternatives and preparation of technical support documentation.



Assessment of Effect of Motor Vehicle Standards on Air Quality

Investigated the effects of past, present and potential future emissions, and fuel standards on motor vehicles in the U.S. on ambient ozone and PM_{2.5} concentrations using emissions, meteorological and air quality modeling with MOVES, WRF, SMOKE and CAMx models. Studied trends in mobile emissions and air quality in Atlanta. Results were published in the journals "Atmospheric Environment" and the "Journal of the Air and Waste Management Association".

NEPA EIS for Organ Mountains National Monument

Technical lead for the air quality analysis to support the EIS and Resource Management Plan (RMP) for the Organ Mountains Desert Peaks National Monument in southern New Mexico. Reviewed existing air quality conditions, prepared emissions inventories of criteria pollutants and precursors and air toxics (hazardous air pollutants) of BLM-authorized sources including transportation and travel management and the use of off-road vehicles, reviewed photochemical modeling and prepared technical documentation for the Affected Environment and Environmental Consequences NEPA sections.

NEPA EIS for Federal-authorized Actions in Oklahoma, Texas, Kansas

The Bureau of Land Management (BLM) prepared a Resource Management Plan under the National Environmental Policy Act (NEPA) to understand impacts from BLM-authorized actions in the states of Oklahoma, Texas, and Kansas. Led the development of construction and operations emissions inventories using MOVES, EPA AP-42 guidance. Led air quality modeling of particulate matter, ozone and other criteria pollutants and atmospheric deposition with CAMx. Led the preparation of air quality technical support documentation for the EIS GHG gas emission inventories and preparation of the Climate Change section of the NEPA EIS and Resource Management Plan (RMP) for the U.S. BLM to guide the management of BLM-administered lands in the states of Oklahoma, Texas, and Kansas. Work included engagement with EPA and other federal/state agencies.

NEPA EIS for Paradox Valley Unit

Supported the U.S. Bureau of Reclamation in the analysis of their proposed action under NEPA to construct and operate facilities for the collection and disposal of saline groundwater at Paradox Valley. Technical lead for the air quality analysis for this project which involved a new injection well, access roads, bridges, an easement from the Colorado Department of Transportation and a treatment plant as needed. Used MOVES model, AP-42 and other data to develop a detailed emissions inventory of criteria/hazardous air pollutants and GHGs from mobile sources (on-road, off-road, portable), stationary sources, and fugitive dust during construction and operational phases under the NEPA alternatives.

NEPA EIS for Extension of Generating Station

Led air quality and climate change analyses for the EIS required under NEPA for the lease extension of a coal-fired power plant in Arizona. Sources analyzed included the electric generating utility stacks, nearby coal mine, auxiliary equipment, transmission lines, generators, tanks, on-road and non-road emission sources and fugitive emissions. Criteria air pollutants and precursors including CO, NO_x, PM_{2.5}, PM₁₀, SO₂, VOC and ozone and hazardous air pollutants were assessed. Direct, indirect, and cumulative effects were assessed for air quality for NAAQS compliance and visibility and deposition at nearby national parks and forests and other federal Class I and II areas. Coordinated with the NEPA human health and safety and ecological resource specialists to assess the health impacts of air deposition.

NEPA EA for Decommissioning of Generating Station and Associated Sources

Led air quality and climate change analyses for the EA required under NEPA for the retirement of a coal-fired power plant in Arizona and the associated project. The EA leveraged the EIS previously conducted for the short-term lease extension. Sources analyzed included the electric generating utility stacks, auxiliary equipment, stationary sources, on-road and nonroad sources and fugitive emissions. Direct, indirect, and cumulative effects were assessed for air quality for NAAQS compliance for the criteria pollutants.



NEPA Supplemental EIS for the BLM Coastal Plain Oil and Gas Leasing Program

Technical lead for air quality analysis for the Supplemental Environmental Impact Statement (SEIS) performed under NEPA for the BLM Coastal Plain Oil and Gas Leasing Program. As requested by BLM and USFWS, performed regional photochemical modeling with CAMx air quality model of hypothetical oil and gas development in Arctic National Wildlife Refuge Coastal Plain (also known as the 1002 area) to assess potential impacts to air quality, visibility, and deposition. Emission sources considered included oil and gas construction and operation activities, and cumulative emission sources including stationary sources, vehicle and off-road sources, other anthropogenic sources, and natural sources. This modeling analysis was needed to inform the public and cooperating agencies of potential impacts of the oil and gas development in the Coastal Plain. Prepared air quality technical support document for the SEIS.

NEPA Supplemental EIS for Resource Management Plan Amendment for BLM Buffalo Wyoming Field Office

Technical lead for the air quality analysis required by the Bureau of Land Management (BLM) under NEPA for a Supplemental Environmental Impact Statement (SEIS) for a Resource Management Plan (RMP) amendment for BLM administered public lands, including Federal mineral estate, within the Buffalo Field Office, Wyoming. Evaluated trends in criteria and hazardous air pollutants and air quality related values (nitrogen and sulfur deposition and visibility) in the planning area and nearby Federal Class I areas. Reviewed and prepared emissions of GHGs and non-GHGs (criteria and hazardous air pollutants and volatile organics) for emission generating activities in the planning area. Incorporated prior air quality modeling emissions and results. Prepared the air quality and climate change sections of the SEIS.

NEPA Supplemental EIS for Resource Management Plan Amendment for BLM Miles City Montana Field Office

Led the technical analysis and preparation of the air quality section for the SEIS under NEPA to support a RMP amendment for the BLM Miles City Field Office, Montana. Services included development of emissions inventories, review of data, tiering to prior air quality emissions and modeling, assessment of the air quality impacts of the potential downstream combustion of coal and oil and gas, and preparation of technical support documentation for the SEIS. Discussed cumulative GHG emissions and climate change and air quality impacts for NEPA alternatives.

NEPA EIS for Rosebud Mine

Led the air quality modeling of fugitive and secondary particulate matter, trace metals, SO₂, NO_x, NH₃ and ozone, and the preparation of air quality and climate change sections of the NEPA EIS for the Rosebud coal mine Area F expansion in Montana. Studied potential direct effects due to the mine and indirect effects due to the nearby power plant. Applied AERMOD and CAMx to characterize direct, indirect and cumulative effects. The process involved numerous discussions with stakeholders including Office of Surface Mining Reclamation and Enforcement (OSMRE) and BLM Montana.

NEPA Supplemental EIS for ConocoPhillips Greater Mooses Tooth-2 Oil and Gas Project

Supported BLM in the preparation of the Supplemental Environmental Impact Statement (SEIS) for the proposed ConocoPhillips GMT-2 oil and gas development on Alaska's North Slope. Performed air quality modeling with CALPUFF to assess impacts of emissions from the project and other cumulative sources on ambient air concentrations of ozone, particulate matter, NO₂ and SO₂, and visibility and acidic deposition near the project and at the Arctic National Wildlife Refuge and Gates of the Arctic.

NEPA EIS for Gold Mine

Senior NEPA Advisor for an EA and EIS required to assess the modification of the mine plan of operations for a gold mine in California. Reviewed emissions inventories for criteria and hazardous air pollutants, dispersion modeling methods, responses to USEPA comments and technical documentation for the EA. Reviewed proposed modeling approach for assessing air and GHG impacts of mine expansion. Reviewed the development of emissions inventories of methane, CO₂ and N₂O, and calculation of social cost of GHGs and other climate change impact assessment metrics following CEQ regulations.



NEPA EIS for BLM North Dakota Resource Development Plan and EIS

Led the Air Quality and Climate Change Analysis for the NEPA EIS and Resource Management Plan (RMP) for the U.S. BLM North Dakota Field Office to inform the assessment of the impact of oil and natural gas and mining activities on federal lands and other cumulative stationary and onroad/nonroad and other anthropogenic and natural sources. Conducted air quality modeling with CAMx for PM_{2.5}, PM₁₀, ozone, CO, NO_x and other criteria pollutants and air quality related values such as deposition and visibility impairment at federal Class I areas and tribal reservations.

NEPA EIS and RMP for Big Game Corridors

NEPA Specialist and Technical Lead for Air Quality and GHG-Climate. The purpose of this EIS was to adopt Bureau of Land Management (BLM) Resource Management Plans to restrict oil and gas production on federal lands to protect the habitat of big game in Colorado. The scope involved development of oil and gas emissions inventories for criteria and hazardous air pollutants and GHGs for alternatives with stipulations and limitations in selected areas with big game habitat, disclosure of stationary, mobile and natural source emissions, tiering to prior BLM modeling, preparation of GHG emissions for RFDs, preparation of NEPA chapters, and agency discussions.

Florida Mercury TMDL Study

Assisted Florida electric utilities in a study of the sources of atmospheric mercury deposition to Florida and conducted discussions with the Florida DEP on the proposed statewide mercury Total Maximum Daily Load (TMDL) regulations. The Florida mercury TMDL was derived after examination of other TMDLs including the Minnesota statewide TMDL, the Northeast regional TMDL and the Arkansas TMDL. Also performed a statistical analysis of temporal trends in Hg emissions and deposition in Florida and presented findings at the 10th International Conf. on Mercury as a Global Pollutant in Halifax, Canada.

Colorado Air Resource Management Modeling Study (CARMMS)

Technical Lead for the BLM CARMMS studies that assessed the air quality and GHG/climate change impacts of new federal mining and oil and natural gas (methane), coal and oil power plants, cement plants and other cumulative emission sources in each of the BLM Colorado Field Office planning areas. Emissions inventories were developed for emission scenarios for future years for criteria/hazardous air pollutants and GHGs. Modeling was performed with CAMx with over 20 source apportionment groups for ozone and PM precursor emissions. Meteorological inputs were prepared for AERMOD and CALPUFF modeling. This pioneering study serves as the programmatic basis for several NEPA EAs in Colorado.

NEPA EIS and RMP for BLM Uncompahgre Field Office

Air Quality Lead and NEPA Specialist for Air Quality and GHG-Climate. The U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) required services to assist in NEPA compliance in preparation of an EIS and potential Resource Management Plan Amendment (RMPA) for the Uncompahgre Field Office (UFO) located in Montrose, Colorado. The scope involved review of existing conditions in the affected environment, development of emissions inventories for criteria and hazardous air pollutants and GHGs for alternatives with stipulations and limitations in selected areas, tiering to prior air quality modeling, preparation of GHG emissions for RFDs, preparation of NEPA chapters, and regulatory agency discussions.

NEPA EIS for Potash Mine

Provided NEPA oversight for the air dispersion modeling and preparation of technical support documentation to inform the Environmental Impact Statement for a large potash mining project in western Utah. Technical services included preparation of air quality modeling protocol, development of emission inventories, modeling with AERMOD, characterization of fugitive dust PM_{2.5} and PM₁₀ at the site, and engagement with lead and cooperating agencies (U.S. BLM, Utah DEQ and EPA).

**NEPA EIS for Open-pit mining project**

Directed a multi-pronged monitoring/modeling study and prepared technical support documents for the EIS for a proposed open pit gold mining project in Alaska. This included meteorological modeling with WRF, design of an air monitoring program, characterization of the impact of a natural gas pipeline, fugitive dust, development of emission inventories, as well as global, regional, and local-scale air quality modeling (CALPUFF, CMAQ, GEOS-Chem) of anthropogenic and natural sources.

Gravel Quarry Ambient Air Monitoring

Led an ambient air quality monitoring and data analysis study near a gravel quarry in Texas in response to public complaints about fugitive dust. Samples were taken at upwind and downwind locations with a FRM filter-based sampler for PM₁₀ and particulate metals, a summa canister for VOC, and polyvinyl chloride (PVC) filter and aluminum cyclone for respirable silica. The measurements were compared to the NAAQS and EPA Regional Screening Levels and other monitoring data in the state.

Air Watershed Model Linkage

Designed, developed, and applied an interface between two advanced atmospheric and aquatic models in coordination with watershed modelers to trace the fate of mercury, sulfur, and nitrogen compounds from air emissions to ecosystem impacts.

CAREER

2010 – Current: Principal, Ramboll

1997-2010: Project Manager, Atmospheric and Environmental Research, Inc.

AFFILIATIONS

National Association of Environmental Professionals

Air and Waste Management Association

EXPERT SUPPORT

- Testified on mercury atmospheric deposition before Colorado Air Quality Control Commission
- Testified on mercury emission control impacts before Illinois Pollution Control Board

AWARDS

Winning team in a national NEPA Artificial Intelligence competition organized by the U.S. Department of Energy Pacific Northwest National Laboratory called "LLMs for Environmental Reviews", July 2024

NEPA TRAINER EXPERIENCE

NEPA Training workshops for environmental professionals in the United States, National Association of Environmental Professionals, 2023 and 2024.

SELECTED PUBLICATIONS AND PRESENTATIONS

Vijayaraghavan, K., 2024. "Using Artificial Intelligence to Improve the Efficiency of NEPA Reviews". National Association of Environmental Professionals Annual Conference. Minneapolis, May

Vijayaraghavan, K., and R. Beardsley. 2023. "Take a Hard Look: The Evolution of NEPA Air Quality and Climate Change Assessments". National Association of Environmental Professionals Annual Conference. Phoenix, May.

Vijayaraghavan, K., S. Libicki, R. Beardsley, J. Jung, S. Ojha. 2020. "Modeling of Atmospheric Mercury Deposition in India." Book Chapter in "Urban Air Quality Monitoring, Modelling and Human Exposure Assessment". Eds. S. Nagendra, U. Schlink, A. Müller, M. Khare. Springer Transactions in Civil and Environmental Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-15-5511-4_13.

Vijayaraghavan, K., C. Pollman. 2019. "Mercury Emission Sources and Contributions of Atmospheric Deposition to the Everglades". Book Chapter in Mercury and the Everglades: A Synthesis and Model for Complex Ecosystem Restoration by Springer Press.

- Vijayaraghavan, K. and C.D. Pollman. 2019. Atmospheric Deposition Flux of Mercury to the Everglades. Book Chapter in *Mercury and the Everglades: A Synthesis and Model for Complex Ecosystem Restoration*. Eds. Pollman, Rumbold, Axelrad. Springer Press.
- Cho, S., K. Vijayaraghavan, D. Spink, B. Cosic, M. Davies, J. Jung. 2017. "Assessing the effects of oil sands related ozone precursor emissions on ambient ozone levels in the Alberta oil sands region, Canada". *Atmos. Env.*, 168, 62-74.
- Cho, S., K. Vijayaraghavan, D. Spink, J. Jung, R. Morris, R. Pauls. 2017. "Assessment of regional acidifying pollutants in the Athabasca oil sands area under different emission scenarios". *Atmos. Env.*, 156, 160-168.
- Vijayaraghavan, K., C. Lindhjem, B. Koo, A. DenBleyker, E. Tai, T. Shah, Y. Alvarez, G. Yarwood. 2016. Source Apportionment of Emissions from Light Duty Gasoline Vehicles and other Sources in the United States for Ozone and Particulate Matter. *Journal Air and Waste Manag. Assoc.*, 66, 98-119.
- Vijayaraghavan, K., S. Cho, R. Morris, D. Spink, J. Jung, R. Pauls, K. Duffett. 2016. "Photochemical model evaluation of the ground-level ozone impacts on ambient air quality and vegetation health in the Alberta oil sands region: Using present and future emission scenarios." *Atmos. Env.*, 141, 209.
- Vijayaraghavan, K., A. DenBleyker, L. Ma, C. Lindhjem, G. Yarwood. 2014. "Trends in On-Road Vehicle Emissions and Ambient Air Quality in Atlanta, Georgia, USA From the Late 1990s Through 2009." *Journal of Air and Waste Management Association*.
- Vijayaraghavan, K., L. Levin, L. Parker, G. Yarwood, and D. Streets. 2014. "Response of Fish Tissue Mercury in a Freshwater Lake to Local, Regional, and Global Changes in Mercury Emissions." *Environ Toxicol Chem*, Jun; 3 (6): 1238-47.
- Vijayaraghavan, K., C. Lindhjem, A. DenBleyker, U. Nopmongkol, J. Grant, E. Tai, G. Yarwood. 2012. "Effects of Light Duty Gasoline Vehicle Emission Standards in the United States on Ozone and Particulate Matter." *Atmos. Environ.*, 60, 109-120, [dx.doi.org/10.1016/j.atmosenv.2012.05.049](https://doi.org/10.1016/j.atmosenv.2012.05.049).
- Harris, R.C., C. Pollman, W. Landing, D. Evans, D. Axelrad, D. Hutchinson, S.L. Morey, E. Sunderland, D. Rumbold, D. Dukhovskoy, D. Adams, K. Vijayaraghavan, C. Holmes, R.D. Atkinson, T. Myers. 2012. "Mercury in the Gulf of Mexico: Sources to Receptors." *Environ. Res.* 119, 42-52.
- Harris, R.C., C. Pollman, D. Hutchinson, W. Landing, D. Axelrad, S.L. Morey, D. Dukhovskoy, D. Adams, K. Vijayaraghavan. 2012. "A Screening Model Analysis of Mercury Sources, Fate and Bioaccumulation in the Gulf of Mexico." *Environ. Res.* 119, 53-63.
- Zhang, L., P. Blanchard, D. Johnson, A. Dastoor, A. Ryzhkov, C.J. Lin, K. Vijayaraghavan, D. Gay, T.M. Holsen, J. Huang, J.A. Graydon, V.L. St. Louis, M.S. Castro, E.K. Miller, F. Marsik, J. Lu, L. Poissant, M. Pilote, K.M. Zhang. 2012. "Assessment of Modeled Mercury Dry Deposition Over the Great Lakes Region." *Environ. Pollut.*, 161. 272-83.
- Karamchandani, P., K. Vijayaraghavan, G. Yarwood. 2011. "Sub-Grid Scale Plume Modeling." *Atmosphere*. 2, 389-409, doi: 10.3390/atmos2030389.
- Vijayaraghavan, K., J. Herr, S.-Y. Chen, E. Knipping. 2010. "Linkage Between an Advanced Air Quality Model and a Mechanistic Watershed Model." *Geosci. Model Dev. Discuss.*, 3, 1503-1548.
- Vijayaraghavan, K., C. Seigneur, R. Balmori, S.-Y. Chen, P. Karamchandani, J.T. Walters, J.J. Jansen, J.E. Brandmeyer, E.M. Knipping. 2010. "A Case Study of the Relative Effects of Power Plant NO_x and SO₂ Emission Reductions on Atmospheric Nitrogen Deposition." *J. Air Waste Manag.*, 60. 287-293.
- Herr, J. W., K. Vijayaraghavan, E. Knipping. 2010. "Comparison of Measured and MM5 Modeled Meteorology Data for Simulating Flow in a Mountain Watershed." *Journal of the American Water Resources Association (JAWRA)*, 46, 1255-1263, doi: 10.1111/j.1752-1688.2010.00489.x.
- Karamchandani, P., K. Vijayaraghavan, S.-Y. Chen, R. Bronson, E.M. Knipping. 2010. "Development and Application of a Parallelized Version of the Advanced Modeling System for Transport, Emissions, Reactions and Deposition of Atmospheric Matter (AMSTERDAM)-1: Model Performance Evaluation And Impacts of Plume-In-Grid Treatment." *Atmos. Poll. Res.*, 1. 260-270.
- Karamchandani, P., K. Vijayaraghavan, S.-Y. Chen, R. Bronson, E.M. Knipping. 2010. "Development and Application of a Parallelized Version of the Advanced Modeling System for Transport, Emissions, Reactions and Deposition of Atmospheric Matter (AMSTERDAM)-2: Source Region Contributions." *Atmos. Poll. Res.*, 1. 271-279.

- Vijayaraghavan, K., Y. Zhang, C. Seigneur, P. Karamchandani, H. E. Snell. 2009. Export of Reactive Nitrogen from Coal-Fired Power Plants in the US: Estimates from a Plume-In-Grid Modeling Study." *J. Geophys. Res.*, 114, D04308, doi: 10.1029/2008JD010432.
- Bullock, O. R., D. Atkinson, T. Braverman, K. Civerolo, A. Dastoor, D. Davignon, J. Ku, K. Lohman, T. Myers, R. Park, C. Seigneur, N. Selin, G. Sistla, K. Vijayaraghavan. 2009. "An Analysis of Simulated Wet Deposition of Mercury From the North American Mercury Model Intercomparison Study." *J. Geophys. Res.*, 114, D08301, doi: 10.1029/2008JD011224.
- Seigneur, C., K. Vijayaraghavan, K. Lohman, L. Levin. 2009. "The AER/EPRI Global Chemical Transport Model for Mercury (CTM-Hg), Chapter 21 in Mercury Fate and Transport in the Global Atmosphere: Emissions, Measurements and Models." N. Pirrone, R.P. Mason, eds., Springer, Norwell, MA, USA.
- Zhang, Y., K. Vijayaraghavan, X.-Y. Wen, H. E. Snell, M. Z. Jacobson. 2009. "Probing into Regional Ozone and Particulate Matter Pollution in the United States: 1. A 1 Year CMAQ Simulation and Evaluation Using Surface and Satellite Data." *J. Geophys. Res.*, 114, D22304, doi: 10.1029/2009JD011898.
- Zhang, Y., X.-Y. Wen, K. Wang, K. Vijayaraghavan, M. Z. Jacobson. 2009. "Probing into Regional O₃ and Particulate Matter Pollution in the United States: 2. An Examination of Formation Mechanisms Through a Process Analysis Technique and Sensitivity Study." *J. Geophys. Res.*, 114, D22305, doi: 10.1029/2009JD011900.
- Vijayaraghavan, K., H.E. Snell, C. Seigneur. 2008. "Practical Aspects of Using Satellite Data in Air Quality Modeling." *Environ. Sci. Technol.*, 42, 8187-8192.
- Vijayaraghavan, K., P. Karamchandani, C. Seigneur, R. Balmori, S.-Y. Chen. 2008. "Plume-In-Grid Modeling of Atmospheric Mercury." *J. Geophys. Res.*, 113, D24305, doi: 10.1029/2008JD010580.
- Bullock, O. R., D. Atkinson, T. Braverman, K. Civerolo, A. Dastoor, D. Davignon, J. Ku, K. Lohman, T. Myers, R. Park, C. Seigneur, N. Selin, G. Sistla, K. Vijayaraghavan. 2008. "The North American Mercury Model Intercomparison Study (NAMMIS): Study Description and Model-To-Model Comparisons." *J. Geophys. Res.*, 113, D17310, doi: 10.1029/2008JD009803
- Vijayaraghavan, K., C. Seigneur, P. Karamchandani, S-Y. Chen. 2007. "Development and Application of a Multi-Pollutant Model for Atmospheric Mercury Deposition." *J. Applied Meteorology and Climatology*, 46, 1341-1353.
- Vijayaraghavan, K., P. Karamchandani, C. Seigneur. 2006. "Plume-In-Grid Modeling of Summer Air Pollution in Central California." *Atmos. Environ.*, 40, 5097-5109.
- Seigneur, C., K. Lohman, K. Vijayaraghavan, J. Jansen, L. Levin. 2006. "Modeling Atmospheric Mercury Deposition in the Vicinity of Power Plants." *J. Air Waste Manag. Assoc.*, 56, 743-751.
- Pun, B., C. Seigneur, K. Vijayaraghavan, S.-Y. Wu, S.-Y. Chen, E. Knipping, N. Kumar. 2006. "Modeling Regional Haze in the BRAVO Study Using CMAQ-MADRID." 1: Model evaluation. *J. Geophys. Res.*, 111, D06302.
- Karamchandani, P., K. Vijayaraghavan, S-Y. Chen, C. Seigneur, E.S. Edgerton. 2006. "Plume-in-Grid Modeling for Particulate Matter." *Atmos. Environ.*, 40, 7280-7297.
- Seigneur, C., K. Vijayaraghavan, K. Lohman. 2006. "Atmospheric Mercury Chemistry: Sensitivity of Global Model Simulations to Chemical Reactions." *J. Geophys. Res.*, 111, D22306, doi: 10.1029/2005JD006780.
- Karamchandani, P., K. Vijayaraghavan, S-Y. Chen, C. Seigneur, E.S. Edgerton. 2006. "Plume-in-Grid Modeling for Particulate Matter." *Atmos. Environ.*, 40, 7280-7297.
- Zhang, Y. K. Vijayaraghavan, C. Seigneur. 2005. "Evaluation of Three Probing Techniques in a Three-Dimensional Air Quality Model." *J. Geophys. Res.*, 110, D02305, doi: 10.1029/2004JD005248.
- Seigneur, C., K. Vijayaraghavan, K. Lohman, P. Karamchandani, C. Scott. 2004. "Global Source Attribution for Mercury Deposition in the United States." *Environ. Sci. Technol.*, 38, 555-569.
- Seigneur, C., K. Vijayaraghavan, K. Lohman, P. Karamchandani, C. Scott. 2004. Modeling the Atmospheric Fate and Transport of Mercury Over North America: Power Plant Emission Scenarios." *Fuel Processing Technology*, 85, 441-450.



- Zhang, Y., B. Pun, K. Vijayaraghavan, S. Wu, C. Seigneur, S. Pandis, M. Z. Jacobson, A. Nenes, J. Seinfeld. 2004. "Development and Application of the Model of Aerosol Dynamics, Reaction, Ionization and Dissolution (MADRID)." J. Geophys. Res., 109, D01202.
- Zhang, Y., B. Pun, S.-Y. Wu, K. Vijayaraghavan, C. Seigneur. 2004. "Application and Evaluation of Two Air Quality Models for Particulate Matter for a Southeastern US Episode." J. Air Waste Manag. Assoc., 54, 1478-1493
- Zhang, Y., B. Pun, S.-Y. Wu, K. Vijayaraghavan, C. Seigneur. 2004. "Application and Evaluation of Two Air Quality Models for PM for a Southeastern US Episode." J. Air Waste Manag. Assoc., 54, 1478-1493.
- Seigneur, C., K. Lohman, K. Vijayaraghavan and R.-L. Shia. 2003. "Contributions of Global and Regional Sources to Mercury Deposition in New York State." Environ. Pollut., 123, 365-373.
- Seigneur, C., P. Karamchandani, K. Vijayaraghavan, K. Lohman, R.-L. Shia, L. Levin. 2003. "On the Effect of Spatial Resolution on Atmospheric Mercury Modeling." Sci. Total Environ., 304, 73-81.
- Seigneur, C., K. Vijayaraghavan, K. Lohman, P. Karamchandani, C. Scott. 2003. "Simulation of the Fate and Transport of Mercury in North America." Journal de Physique IV, 107, 1209-1212.
- Karamchandani, P., C. Seigneur, K. Vijayaraghavan, S.-Y. Wu. 2002. "Development and Application of a State-of-the Science Plume-In-Grid Model." J. Geophys. Res., Vol. 107, No. D19, 4403.
- Seigneur, C., P. Karamchandani, K. Lohman, K. Vijayaraghavan, R.-L. Shia. 2001. "Multi-Scale Modeling of the Atmospheric Fate and Transport of Mercury." J. Geophys. Res. 106. 27795-27809.
- Pai, P., K. Vijayaraghavan, C. Seigneur. 2000. "Particulate Matter Modeling in the Los Angeles Basin Using SAQM-AERO." J. Air Waste Manag. Assoc., 50, 32-42.
- Seigneur, C., C. Tonne, K. Vijayaraghavan, P. Pai. 2000. "The Sensitivity of PM_{2.5} Source-Receptor Relationships to Atmospheric Chemistry and Transport in a Three Dimensional Air Quality Model." J. Air Waste Manage. Assoc., 50, 428435.
- Vijayaraghavan, K. and K.S. Surana, 1997. "P-Version Least-Squares Finite Element Formulation of a System of Convection-Reaction Nonlinear Equations - Fixed Bed O-Xylene Oxidation." Computers and Structures, 62, 539-554.